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ABSTRACT

This study examined the effects of animation and practice on factual and application learning in computer based instruction (CBI), and the extent to which animation and practice promoted near and far transfer of these learning outcomes. Subjects were 192 fourth, fifth, and sixth graders, and the CBI content was an elementary physics lesson in Newtonian mechanics. Two levels of practice (Relevant Practice and Irrelevant Practice) were crossed with three levels of graphic type (Graphic, Animated Graphic, and No Graphic) and two levels of text type (Text and No Text). No significant differences were found for the between-subjects factors of practice, graphic type, and text type. Among the within-subject factors (Learning Outcome and Transfer), a main effect was for transfer, i.e., subjects performed significantly better on far transfer questions than on near transfer questions. A significant interaction was also detected among Learning Outcome and Transfer, i.e., far learning was facilitated for factual learning, whereas no difference in transfer was detected for application learning. Results of the data analyses are displayed in two tables. (21 references) (Author/EW)

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THE EFFECTS OF COMPUTER ANIMATED ELABORATION STRATEGIES AND PRACTICE ON FACTUAL AND APPLICATION LEARNING IN AN ELEMENTARY SCIENCE LESSON

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THE EFFECTS OF COMPUTER ANIMATED ELABORATION STRATEGIES AND PRACTICE ON FACTUAL AND APPLICATION LEARNING IN AN ELEMENTARY SCIENCE LESSON

ABSTRACT

The purpose of this study was to examine the effects of animation and practice on factual and application learning in computer-based instruction (CBI). Also studied was the extent to which animation and practice promoted near and far transfer of these learning outcomes. Subjects consisted of 192 elementary school students. The CBI content was an elementary physics lesson in Newtonian mechanics. Two levels of Practice (Relevant Practice, Irrelevant Practice) were crossed with three levels of Graphic Type (Graphic, Animated Graphic, No Graphic) and two levels of Text Type (Text, No Text). No significant differences were found for the between-subjects factors of Practice, Graphic Type, and Text Type. Among the within-subject factors (Learning Outcome, Transfer) a main effect was found for transfer: subjects performed significantly better on far transfer questions than near transfer questions. A significant interaction was detected between Learning Outcome and Transfer: far learning was facilitated for factual learning, whereas no difference in transfer was detected for application learning.

INTRODUCTION

Instructional design has evolved into a complex science involving the manipulation of many instructional variables. Effective delivery of instruction has consistently been the focus of much attention in instructional design. The recent availability of microcomputers has provided designers with many instructional alternatives as well as the need to consider important instructional decisions. The potential of the computer as an effective instructional delivery system has been carefully reviewed and studied (see, for example, Edwards, Norton, Taylor, Weiss & Dusseldorp, 1975; Bangert-Drowns, Kulik, & Kulik, 1985, and Clark, 1985).

Computer technology affords designers with a myriad of useful design options. Features such as immediate and informative feedback, lesson branching, lesson management, and visuals have been discussed and reviewed in length. Designers can also effectively incorporate a wide range of teaching strategies and activities into computer-based instruction (CBI).

Potentially unique features of CBI have been discussed and debated. Some, such as Clark (1983), have cautioned against concentrating too heavily on the features of any one particular medium. Clark has asserted that virtually all results found in CBI research stem from purely instructional variables and are only indirectly associated with the computer. Although controversy remains (see, Petkovich & Tennyson, 1984 vs. Clark, 1983), it appears clear that many features of the computer deserve greater attention among researchers. Animation is one such feature which can be more easily incorporated into CBI than perhaps other delivery systems. Although instruction typically uses animation as an extrinsic motivator, there is a need to investigate the use of animation to directly or indirectly support or enhance instruction. An example of computer animation used directly in instruction is an animated block accelerating down an inclined plane to teach a concept in a physics class. Recent research on the effectiveness of animation as an aid to instruction has failed to demonstrate that animation improves learning (see, for example, A. Caraballo, 1985; J. Caraballo, 1985; King, 1975; Moore, Nawrocki, & Simutis, 1979; Rieber & Hannafin, in press).

The lack of empirical support for animation presents an apparent discrepancy between hypothesized animation effects (as supported by a theoretical perspective of the importance of providing information in verbal and visual representations to promote redundant encoding) and the empirical evidence to date. Research in the area of cognitive psychology points to the apparent retrieval advantages of multiple encoding at the time of learning. Mental imagery researchers (Bower, 1972 and Paivio, 1979) have recognized mental imagery as one of the primary mental structures,

along with verbal representations. Many studies (Bower, 1972; Paivio, 1979; Dwyer, 1978) point to the power of pictures over abstract words for purposes of higher levels of retention. The problem seems to rest in the need to define appropriate contexts where the potentially powerful visual effect of animation can be used most effectively.

Practice is another instructional variable which has been studied extensively (Anderson & Biddle, 1975; Hamaker, 1986). Practice in CBI typically comprises a series of questions presented during or following instruction. CBI practice serves three functions: 1) to establish and maintain attention; 2) to facilitate encoding; and 3) to provide opportunities for rehearsal (Wager & Wager, 1985). The application of practice questions during CBI is based on the adjunct questioning research of Rothkopf (1966) and others. CBI studies have shown that practice can be a very powerful influence on student achievement (Hannafin, Phillips, Rieber, & Garhart, in press; Hannafin, Phillips, & Tripp, 1986). Although practice is a proven and robust instructional technique, even current reviewers caution against sweeping generalizations (see Hamaker, 1986). There is a need to study the effects of computerized practice, especially when used in the presence of other complex instructional techniques, such as animation.

There were two primary purposes to this study: 1) examine the effects of animation and practice on factual and application learning in a CBI lesson; and 2) investigate the extent to which animation and practice promoted near and far transfer of these learning outcomes. It was hypothesized that students provided with verbal and graphic elaborations of lesson content would achieve higher posttest scores than groups receiving only verbal or only graphic elaborations. It was further hypothesized that practice would be of greatest value where the elaboration support was minimal.

METHODS

Subjects

The subjects consisted of 192 fourth, fifth, and sixth graders from a rural public elementary school. Participation was voluntary and selection based on parent consent. The subjects represented a typical cross-section of elementary school students. In addition, three fifth grade classes from another public school served as a pilot subjects to validate the materials as well establish reliability on the instruments.

CBI Lesson Content

The CBI lesson used as the instructional content for this study was first developed for a previous study (see Rieber & Hannafin, in press). This lesson described and explained Isaac Newton's Laws of Motion. The lesson material was divided into four parts: 1) introductory material; 2) motion resulting from equal forces in opposite directions in one dimensional space; 3) motion resulting from unequal forces in opposite directions in one dimensional space; and 4) motion resulting from equal and unequal forces in two dimensional space.

The first lesson part introduced the learner to Isaac Newton's formal discovery of certain physical laws. This part also initiated the sequence of learning activities used for the rest of the lesson. Most of the information presented in the first part was factual in nature. The second part introduced the concept that equal but opposite forces are needed to cause objects to stop. This section dealt only with one-dimensional space. The third part expanded this notion to include the effects of unequal forces acting upon a stationary object. The final direction and speed of an object is a combination of all of the forces from both directions. The third part also presented these concepts in one-dimensional space. Finally, the fourth part added the notion of two-dimensional space to the above concepts. Again, the final direction and speed of the object results systematically from the sequence of forces which acted upon it.

All instruction was presented at an introductory level with the technical descriptions of the forces of gravity and friction removed. Approximately 45 minutes was required to complete the

lesson.

Lesson Versions

Elaboration strategies were embedded at various locations within the lesson. The locations of these elaboration strategies were determined by the performance of students in a pilot study. The elaboration strategies were added to the lesson in areas found to be the most difficult and needing additional instruction. Two factors (Text Type, Graphic Type) were used to determine the nature of the embedded elaboration strategies: two levels of Text (Text, No Text) were crossed with three levels of Graphic (Graphic, Animated Graphic, No Graphic). The combination of these two factors gave the following treatment permutations: text only, text plus graphic, text plus animated graphic, graphic only, animated graphic only, no text/no graphic.

The text and graphic factors were crossed by a practice factor with two levels (Relevant Practice, Irrelevant Practice). Relevant practice consisted of four multiple-choice questions after each of the four lesson parts: two factual and two application. Feedback in the form of knowledge of correct results was provided. Irrelevant practice consisted of a noninstructional activity which required approximately the same time to complete as the relevant practice. The format of the noninstructional activity was also multiple-choice questions, however, the questions concerned information which was irrelevant to the lesson content.

Dependent Measures

Posttest. A 37-item posttest was developed which consisted of two types of questions: 16 factual and 21 application. These learning outcomes correspond to verbal information and rule-using, respectively, as defined by Gagne' (1977). A multiple-choice question format (1 answer and 4 distractors) was used to test the above learning outcomes. All test questions were presented to the students by computer.

A total of 19 questions measured near transfer and 18 questions measured far transfer: 9 factual questions and 10 application questions measured near transfer; 7 factual questions and 11 application questions measured far transfer. An example of near transfer would be a question presented in the context of a ball being kicked. An example of far transfer would be a question presented using a wooden block instead of a ball. Overall test reliability, as determined during the pilot study, was .91. Content validity was established by an expert panel review.

Student processing time. The time required by students to process each of the instructional frames was also collected. Processing time was measured as the time taken by students to press a key to continue after a screen prompt had been given. Response time was calculated by the computer and rounded to the nearest second.

Procedures

In order to determine the content validity and reliability of the materials as well as to substantiate the instructional design of the materials, a pilot study was conducted using a small sample of fifth grade students. In this pilot study, the four instructional parts (introductory, equal forces in one dimension, unequal forces in one dimension, and unequal forces in two dimensions) were presented in an all-text form without any embedded elaboration strategy. Data from this pilot study was used to determine the validity and reliability of the test items in order to help determine the final selection of appropriate test items. Also, this data was used to determine where supplemental instruction in the form of the elaboration strategies was most needed by students.

In the main experiment, students were randomly assigned to one of the 12 treatment conditions. All treatments and data were delivered and recorded by computer. On average, approximately 45 minutes was necessary to complete the lesson.

Design and Data Analysis

In this study a 3 X 2 X 2 X (2 X 2) completely crossed factorial design was used. Three between-subjects factors (Graphic Type, Text Type, and Practice) were crossed with two

within-subjects factors (Learning Outcome, Transfer). The between-subjects factors consisted of: Graphic Type (Graphic, Animated Graphic, No Graphic); Text Type (Text, No Text); and Practice (Relevant Practice, Irrelevant Practice). The within-subjects factors consisted of: Learning Outcome (Fact, Application); and Transfer (Near, Far). A mixed factor analysis of variance (ANOVA) was chosen as an appropriate statistical procedure for the study. This analysis is commonly known as a repeated measures analysis of variance (Winer, 1971). The two within-subjects factors also served as the dependent measures of the posttest.

In addition to the above analysis, a second post hoc analysis of student processing latency of the 17 instructional frames which contained embedded elaboration strategies was conducted using ANOVA procedures.

RESULTS

Learning Effects

The percentage means and standard deviations of posttest scores are contained in Table 1. No main effects were found for Graphic Type, $F(2,180)=.393$, $p=.676$, Text Type, $F(1,180)=.072$, $p=.789$, or Practice, $F(1,180)=.234$, $p=.629$. No main effect was found for Learning Outcome, $F(1,180)=2.285$, $p=.132$. A main effect was found for Transfer, $F(1,180)=4.439$, $p=.037$: learners performed significantly better on far transfer questions than near transfer questions.

No interactions were detected among the between-subjects factors (Graphic Type, Text Type, Practice). However a significant interaction was found for the within-subjects factors (Learning Outcome, Transfer), $F(1,180)=3.911$, $p=.05$. The lesson promoted far learning for factual information, whereas far learning was not facilitated for the acquisition of application learning. A moderately significant interaction was found between the factors of practice and learning outcome, $F(1,180)=3.394$, $p=.067$. When provided with practice, students performed significantly higher on application questions than factual questions.

Insert Table 1 About Here

Processing Time

Means and standard deviations for the total processing time of the 17 instructional frames which contained embedded elaboration strategies are listed in Table 2 by treatment. Once prompted to press a key to proceed, students spent significantly less time viewing lesson frames which contained animated graphics as compared to instruction which contained either graphic or no graphics, $F(2,184)=45.66$, $p<.0001$. Also, and not surprisingly, students spent significantly more time viewing lesson frames which contained additional textual elaborations as compared to students who were not given additional textual support, $F(1,184)=27.29$, $p<.0001$. Apparently, students were taking the time to read all textual information presented.

A significant interaction was detected between the presence of graphics and text, $F(2,184)=3.61$, $p=.029$. Students attended longer when no graphic accompanied additional text.

Insert Table 2 About Here

DISCUSSION

The lack of main effects among the embedded elaboration conditions was surprising. Previous research has demonstrated the power of pictures over abstract words in facilitating understanding of abstract concepts. Some mental imagery researchers have posed that information is encoded into long term memory in two ways: as a mental image and as a verbal representation (Paivio, 1979). It was believed that learners would recall greater amounts of factual information as well as be more successful in solving application questions when provided with instruction which contained both graphic and textual elaboration cues than when no such cues were provided or when these cues provided only graphic or only textual information. The results from this study showed that this was not the case.

There are several possible explanations for the outcomes found in this study. First, it is possible that the students did not attend to the elaboration strategies. That is, although the elaboration strategies provided the potential for additional cognitive processing of the lesson information, the students did not make use of it. Reasons for this are debatable. An analysis of the processing latency for the lesson frames shows that students spent significantly more time viewing lesson frames which contained textually oriented elaboration strategies than similar frames which did not contain this textual information. This data implies that although the learners took longer to view frames with textually oriented information, they did not use the information in an elaborative manner. Students spent significantly less time viewing frames which contained animated graphic elaboration strategies than those with graphics or no graphics. Instead of taking additional time to think about (elaborate) or mentally reconstruct the animated sequence, the learners immediately pressed a key to trigger the presentation of the next lesson frame. When the elaboration strategy was presented in static form (graphic with or without text), learners spent a considerably longer time viewing the frame. The differences in processing time indicates that the learners were processing the elaboration strategies in different ways, but no thresholds for increased learning occurred. It should be noted that although equal amounts of learning occurred, less cognitive processing time was used by the animated graphic group, hence the potential for more efficient learning. The drawback is that the animation sequence takes more time to present than either static graphics or all-text presentations. Instead of attending to the animated instruction, students may have ignored it and spent the time reading other textual material on the screen.

Another probable explanation concerns the nature of the lesson content. The lesson material may have proved too difficult and complex for the students. This level of complexity could have prevented learners from mentally processing the elaboration strategies in the ways in which they were intended. It could have been that the embedded elaborations were instructionally too weak to affect learning, especially given the difficulty of the tasks. Since the elaboration strategies were not included in the validation process, it is difficult to make inferences about their effects.

The significant difference between near and far transfer learning is somewhat surprising. Typically, learning in near transfer situations would be expected to be greater than far transfer situations. One explanation is that the concepts were encoded meaningfully into "real life" contexts. These contexts were natural extensions of the "kicked ball" analogy used in the lesson. This rationale also helps to explain the significant interaction between learning outcome (Fact, Application) and transfer. Learners performed significantly better on factual questions in far transfer settings than on application questions in near transfer settings. The implication is that learners were actively elaborating on the ball example in simple, factually related ways and never fully processed the information in order to use it in solving application questions. If the elaboration strategies had been

effective, as hypothesized, more consistent findings would have been expected.

The lack of main effects for practice was also surprising. Again, this result is probably an artifact of the task difficulty -- the lesson material was probably too complex for the age group. The practice activities were intended to provide opportunities for students to process relevant lesson content. These activities should have helped to simplify the lesson material in order to help students select relevant content. Furthermore, the activities should have encouraged organization and integration of content with prior knowledge and other lesson content. Rather, they appeared to increase the cognitive strain imposed on the students. Students probably perceived the lesson as too demanding and may have chosen to ignore potential practice benefits. Another explanation, though less likely, suggests that insufficient practice was provided. Asking students only four questions after approximately 11 computer frames may have been insufficient to activate adequate processing. No general interpretations of the usefulness of practice as an instructional technique should be inferred. The effectiveness of adjunct questions as practice strategies, under certain guidelines, has been well documented (Hamaker, 1986; Salisbury, Richards, & Klein, 1985; Wager & Wager, 1985).

Although an interaction between practice and elaboration strategy was expected, no interaction was observed. It was expected that when learners were provided good elaborative cues to facilitate appropriate imagery and verbal encoding, they would not rely on the cognitive processes activated by routine practice. Conversely, in the absence of the lesson cues believed to facilitate appropriate levels of encoding, other techniques, such as practice, would be necessary to achieve similar encoding levels. The absence of this interaction is also probably attributable to previous explanations: either the students did not attend to the lesson information appropriately, or the lesson material was too difficult.

This study has raised several questions concerning the relationship between student thought processing, instructional delivery systems, and instructional strategies. Due to an apparent confounding caused by difficult lesson content compounded by relatively ineffective lesson activities, the question of how computer animation may be used to positively affect learning remains largely unanswered. Future researchers should be careful to adequately match the complexity of materials with the maturity of the subjects. Also, replications should systematically validate the effectiveness of additional elaborations. Lessons should be designed to direct the learner to both attend to, and use, elaboration strategies appropriately.

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Table 1

Percentage Means and Standard Deviations of the Posttest Data

			Text			
			Fact		Application	
Graphic Type	Practice		Near	Far	Near	Far
Graphic	Yes	M	46.06	54.88	56.25	53.44
		SD	21.93	25.49	25.53	24.94
	No	M	45.44	50.38	40.00	43.31
		SD	25.94	20.18	25.56	23.76
Animated Graphic	Yes	M	40.56	43.38	44.38	42.75
		SD	18.91	30.18	21.28	24.05
	No	M	52.94	55.00	51.88	51.75
		SD	18.24	26.02	21.98	19.78
No Graphic	Yes	M	53.69	60.31	51.88	47.25
		SD	23.96	29.28	23.73	28.26
	No	M	50.88	53.06	44.38	54.63
		SD	24.30	29.74	25.02	26.86
			No Text			
			Fact		Application	
Graphic Type	Practice		Near	Far	Near	Far
Graphic	Yes	M	46.75	46.94	46.88	41.07
		SD	26.45	27.46	24.42	18.47
	No	M	46.75	48.69	43.13	47.25
		SD	23.48	24.45	24.42	24.28
Animated Graphic	Yes	M	52.31	56.63	49.38	55.12
		SD	28.54	29.51	22.35	23.91
	No	M	47.44	54.06	48.75	45.00
		SD	21.74	24.03	15.86	16.93
No Graphic	Yes	M	44.00	50.44	55.63	56.32
		SD	19.88	23.31	24.21	26.03
	No	M	49.50	48.63	45.00	43.32
		SD	25.34	28.08	20.66	24.44

Notes: n=16 subjects per cell.

Table 2

Mean Processing Time (in Seconds) and Standard Deviations of 17 Instructional Frames Containing Embedded Elaboration Strategies

		Text Type	
Graphic Type		Text	No Text
Graphic	M	212.65	168.74
	SD	97.14	77.57
Animated Graphic	M	83.81	44.72
	SD	94.57	46.90
No Graphic	M	246.47	134.03
	SD	123.19	62.04